

height of 21 kilometers, 5 to 15 kilometers, 40 to 10 kilometers, and 76 to 5 kilometers.

The velocity and direction of each flight was determined for levels of 0.25 kilometer to 1 kilometer and for each 0.5 kilometer above this. Velocities were then resolved into north-south and east-west components. The algebraic sum of these components for four months (November–February) in the wet season and four months (May–August) in the dry season are shown in Fig. 1. The normal meteorological conditions for these months are given in Table 1.

TABLE 1.—Normal meteorological conditions, Apia, Western Samoa

	Mean hourly value of—			Total rainfall
	Temperature	Pressure	Relative humidity	
	° C.	Milli-meters	Per cent	Milli-meters
November–February	26.12	759.47	84.2	352
May–August	25.44	758.87	82.2	104

At the surface there is a slight movement of the air toward the equator, which, as already stated, would be greater except for the shielding effect of hills. From 2.5 kilometers to 8.5 kilometers the air movement has a small poleward component. From this height to 12 kilometers, above which the number of observations is not sufficiently great to be relied on, there is a contrary movement toward the equator; indications are, however, that this equatorward movement does not persist to higher levels.

The low values of the north-south components are not due to large south values being canceled by large north values; the components themselves were consistently low. This was apparent while making the observations, the balloons being taken far out to the westward and then after passing through a very thin layer of nonmoving air were brought back approximately over the heads of the observers.

The east-west components are much simpler; the trade wind movement to the west decreases steadily with altitude, becoming zero at 2.5 kilometers in November–February, and 6.2 kilometers in May–August. The antitrades setting in at these levels continues to increase in velocity to a height of 12 kilometers.

The resultant wind was obtained by combining the components. The data for each period of two months are shown graphically in Figure 2. Owing to the prevailing cloudy weather during January and February, there are few balloon flights, and the intrusion of a westerly wind between the levels 2.0 kilometers and 5.5 kilometers is doubtful. Although the number of observations above the 15 kilometer level is small there seems to be no indication of an upper trade wind at an altitude less than 18 kilometers.

Observations are in progress with two theodolites and special light filters, the latter being of practical value in following balloons against the deep blue skies which occur here.

Acknowledgment is made to Dr. Russell Pemberton for his aid in the computational work and to the Chief of the United States Weather Bureau for the loan of apparatus.

#### HOURLY RAINFALL PROBABILITIES AT LANSING, MICH.

By C. L. RAY

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Following the plan of Feldwisch, whose study of hourly precipitation for Springfield, Ill., appeared recently,<sup>12</sup> the writer has used a somewhat similar method in making an analysis of the Lansing, Mich., records, covering a period of 15 years, 1910–1924, inclusive. The months of May through October have been considered, the records being only occasionally lacking, due to failure of the recording gauge or to freezing temperatures in the extreme months. The tabulations will of course be useful principally to the local station, as requests come to hand for aid in planning rain insurance policies.

A table of frequency percentages for the several days of the months, as April 6, May 12, etc., does not appear to be of very much value, though sometimes information of this nature is requested by those interested in rainfall insurance for a particular day. Hourly frequencies however, reflecting diurnal influences are certainly worthy of some consideration by underwriters and any other proposing to enter into insurance agreements.

In Table 1 is shown the percentage frequency of 0.10 inch or more precipitation within 1, 2, 3, 4, 5, and 6 hours, beginning at midnight, 1 a. m., 2 a. m., etc., for the 24 hours. In Table 2 and Figure 1 the total hourly rainfall for the past 15 years is given, while in Figure 3 is shown the total hourly amounts for the combined six months period.

In June, according to Table 1, the maximum frequency of precipitation of 0.10 inch occurs during the six hours beginning at 4 p. m., while the hours beginning at 11 a. m., 12 noon, etc., until 4 p. m., 5 p. m., and 6 p. m., are all

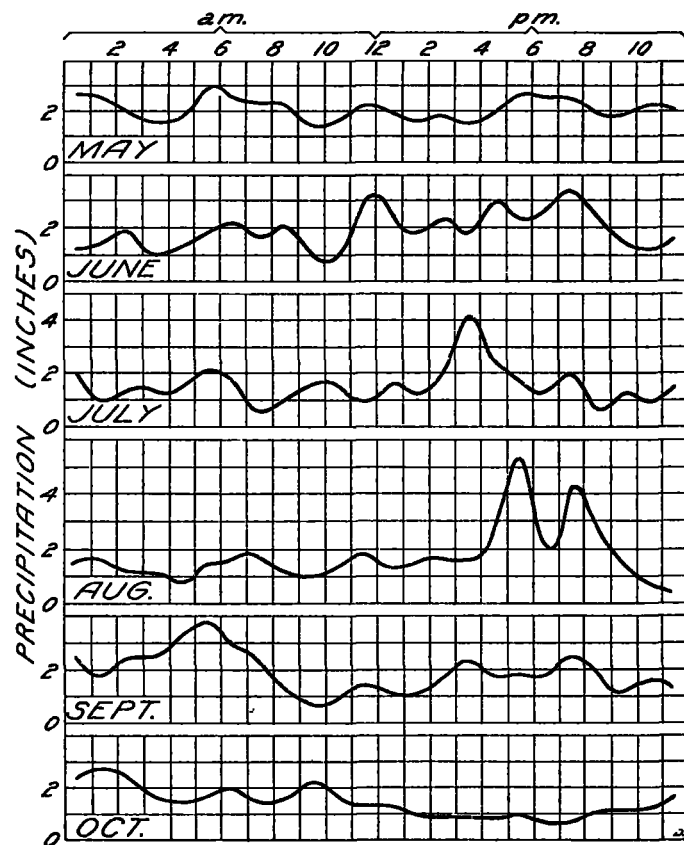


FIG. 1.—Total hourly amounts of precipitation, May to October, 1910–1924, inclusive, Lansing, Mich. Data from Table 2

more favorable than any other hours as the initial hour of a six-hour period within which 0.10 inch of precipitation is most probable. In July the six-hour period beginning at 12 noon is most favorable for the 0.1-inch fall, though only slightly less so are the periods beginning at 11 a. m., 1, 2, and 3 p. m. In August the most favorable hours in this same connection are those

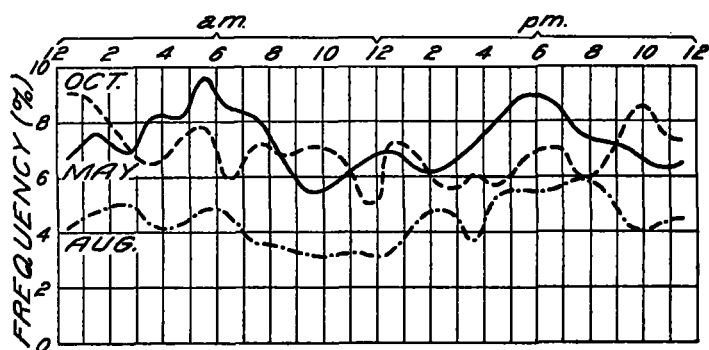


FIG. 2.—Average hourly frequency of rainfall of 0.01 inch or more, Lansing, Mich., for the years 1910-1924, inclusive

beginning at 2 p. m., and 3 p. m., although almost equally favorable are the six-hour periods beginning at 12 noon and 1 p. m. In the spring and autumn months there is a slightly different period of maximum frequency. In May the six hours beginning at 11 p. m., 12 midnight, 1, 2, 3, and 4 a. m. are most favorable, with the period beginning at 2 a. m. showing the highest percentage. In September the hours from midnight to 6 a. m. show the greatest probability of at least 0.10 inch, while in October there is a period of greatest probability running from 7 p. m. until 1 a. m.

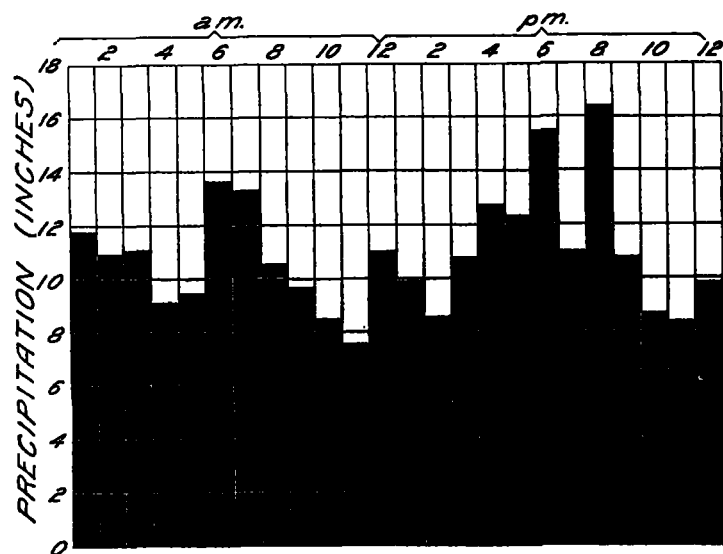


FIG. 3.—Total rainfall in inches for each hour of the day for months of May to October, 1910-1924, inclusive, at Lansing, Mich.

In Table 3 are shown the percentages of actual rainfall for the six hour periods, midnight to 6 a. m., 6 a. m. to 12 noon, etc. By these figures it is seen that during the

summer months the hours from noon to 6 p. m. are most favorable for precipitation, while in May, September, and October there is a slight margin in favor of the hours between midnight and 6 a. m. Thus is shown a rather marked agreement of the results from Tables 1 and 3.

In Table 4 and Figure 2 the lighter precipitation has been included in a calculation of hourly frequency. These lighter rains bring the frequency to a figure from four to seven times greater than the heavier showers the minimum rate of which was placed at 0.10 inch as compared with 0.01 inch for the lighter type. Generally the rainfall of 0.01 inch an hour is too light in total to verify insurance where as a rule there must be at least 0.10 inch of precipitation within four to six hours. The data contained in Table 4 and Figure 2 are interesting, but not as satisfactory a basis for insurance plans as are those tables where heavier showers are considered exclusively. The tabulation of the lighter rainfall does show a period of maximum frequency practically coincident with that of the heavier type, so that as a verification of this time element it may serve a useful purpose.

TABLE 1.—Percentage frequency of the occurrence of 0.10 inch or more precipitation within 1, 2, 3, 4, 5, and 6 hours beginning at midnight, etc., for 24 hours at Lansing, Mich. (years 1910-1924, inclusive)

Month	Length of period (hours)	Period beginning (a. m.) at—											
		Mid-night	1	2	3	4	5	6	7	8	9	10	11
May	1	2.4	2.3	1.3	0.9	1.2	1.4	0.7	1.7	1.2	0.7	0.9	1.4
	2	3.9	3.7	2.7	2.4	1.6	3.2	3.2	3.0	2.2	1.1	1.2	2.2
	3	4.5	3.9	3.7	3.2	3.9	4.5	3.9	4.1	2.9	2.0	2.0	3.3
	4	5.7	5.5	5.5	5.7	5.5	5.7	5.7	4.8	3.9	3.3	3.7	5.0
	5	6.5	6.1	7.2	6.7	7.0	7.2	6.5	5.8	5.2	5.5	5.2	6.1
	6	7.6	7.6	8.2	7.7	7.5	7.4	7.2	6.3	6.1	6.3	5.9	7.0
June	1	.7	.7	1.4	.7	1.0	1.2	1.4	1.2	1.0	.7	.5	1.6
	2	1.7	2.4	2.4	2.1	2.9	3.6	3.4	2.9	1.8	1.1	1.6	2.3
	3	3.1	2.6	3.1	3.3	3.6	4.0	3.6	3.4	2.4	2.7	2.9	3.1
	4	3.8	3.6	3.6	3.8	4.3	4.6	4.6	4.1	4.2	3.6	3.6	4.5
	5	4.5	5.0	5.0	5.0	5.3	5.3	5.5	6.0	5.0	4.8	5.5	5.4
	6	5.0	5.6	5.3	6.0	5.6	6.0	6.5	6.0	5.2	6.0	5.0	7.4
July	1	1.1	.2	.5	1.6	.9	1.2	1.4	.5	.7	.9	.7	.7
	2	1.4	.5	1.6	1.9	1.9	2.5	1.6	.9	1.6	1.4	1.6	1.9
	3	2.1	1.8	2.3	3.0	3.3	3.0	2.3	1.6	1.8	2.5	2.1	3.0
	4	3.3	2.6	3.3	3.5	3.5	3.5	2.5	1.6	2.5	3.0	3.5	3.7
	5	4.1	3.5	3.9	4.2	3.9	3.9	2.8	2.8	3.5	4.4	4.9	6.0
	6	4.6	4.2	4.2	4.6	4.2	4.1	3.5	3.7	4.9	5.3	6.9	6.9
August	1	1.2	1.5	.9	.5	.7	.9	.9	1.2	.7	.7	.9	1.4
	2	2.5	2.1	1.4	1.2	1.9	1.9	1.2	1.6	1.2	1.6	2.1	1.8
	3	3.5	2.6	1.4	2.1	2.5	2.3	1.6	2.5	2.5	2.8	3.2	2.6
	4	3.7	3.0	2.8	2.6	2.8	2.6	2.6	3.5	3.2	3.7	3.7	3.7
	5	3.9	3.5	3.3	2.8	3.3	3.0	3.0	3.9	4.1	3.9	4.4	5.1
	6	4.9	4.9	3.9	3.3	4.2	3.9	3.7	5.1	4.6	5.1	5.8	6.7
September	1	1.9	1.2	1.2	2.1	1.9	2.8	2.3	1.9	1.0	.5	.5	1.4
	2	2.7	2.1	2.3	3.1	4.1	3.6	3.3	2.3	2.1	1.2	1.4	2.3
	3	4.1	3.6	4.6	5.3	5.0	4.5	4.0	3.3	3.1	2.1	2.3	3.6
	4	4.7	5.2	6.5	5.8	5.5	4.8	4.8	4.3	4.0	3.6	3.6	4.3
	5	6.5	6.9	6.9	6.6	5.6	5.5	5.0	5.2	5.0	5.0	4.7	5.6
	6	8.7	7.6	7.8	6.9	6.7	6.0	5.5	6.0	5.8	5.5	5.6	6.0
October	1	1.3	2.1	1.6	1.1	.9	.9	1.1	.7	1.1	1.4	.7	.9
	2	3.9	3.3	1.7	2.0	2.1	1.7	2.3	2.3	2.8	2.2	1.4	1.8
	3	4.5	3.8	2.6	2.8	3.5	2.8	3.5	3.8	3.5	2.6	2.5	3.2
	4	4.8	5.2	3.5	4.2	4.4	3.8	4.5	4.4	3.8	3.3	3.5	4.2
	5	5.8	5.5	4.8	4.8	4.8	5.0	5.6	4.8	4.3	4.8	5.2	4.8
	6	6.5	6.3	5.2	5.2	6.0	5.9	6.3	5.6	5.6	6.0	6.0	5.2
Means	1	1.4	1.3	1.2	1.2	1.1	1.4	1.3	1.2	1.0	.8	.7	1.2
	2	2.7	2.4	2.0	2.1	2.4	2.8	2.5	2.2	2.0	1.4	1.6	2.0
	3	3.6	3.0	3.0	3.3	3.6	3.5	3.2	3.1	2.7	2.4	2.5	3.1
	4	4.3	4.2	4.2	4.3	4.3	4.2	4.1	3.8	3.6	3.4	3.6	4.2
	5	5.2	5.1	5.2	5.0	4.6	5.0	4.7	4.8	4.5	4.7	5.0	5.5
	6	6.2	6.0	5.8	5.6	5.7	5.6	5.4	5.4	5.4	5.7	6.0	6.5

TABLE 1.—Percentage frequency of the occurrence of 0.10 inch or more precipitation within 1, 2, 3, 4, 5, and 6 hours beginning at midnight, etc., for 24 hours at Lansing, Mich. (years 1910-1924, inclusive)—Continued

Month	Length of period (hours)	Period beginning (p. m.) at—											Mean	
		12	1	2	3	4	5	6	7	8	9	10		11
May	1	0.9	0.9	1.5	0.7	1.2	1.4	1.4	1.8	1.8	0.5	0.9	1.3	1.2
	2	2.0	1.7	2.0	2.0	3.0	2.5	3.2	3.0	2.8	2.8	2.6	2.8	2.5
	3	2.4	2.3	3.2	2.8	4.1	4.0	3.9	3.2	3.4	3.2	3.4	4.1	3.4
	4	2.8	4.3	4.5	4.1	6.0	5.8	5.2	5.0	5.0	4.8	5.6	6.0	5.0
	5	5.8	6.1	5.8	5.8	6.4	6.1	5.8	6.1	5.8	5.8	6.3	6.7	6.2
	6	6.3	6.3	6.9	6.3	6.6	6.4	6.9	6.7	6.4	6.4	6.7	7.6	6.6
June	1	1.3	.9	1.6	.7	2.6	2.4	1.2	2.1	2.1	1.7	.7	1.4	1.2
	2	2.5	2.3	2.3	3.1	3.6	3.1	2.9	3.3	4.0	2.9	1.9	1.9	2.6
	3	3.6	3.4	4.5	4.9	4.9	4.7	4.3	5.0	5.0	3.8	2.6	2.9	3.6
	4	4.3	5.4	5.8	5.6	5.8	5.2	5.7	6.4	6.4	4.5	3.8	3.8	4.7
	5	6.6	6.6	6.8	6.7	6.7	6.9	6.7	6.7	6.6	5.5	4.3	5.0	5.7
	6	7.1	7.4	7.6	7.6	8.2	7.8	7.9	7.2	6.9	6.4	5.0	5.5	6.4
July	1	1.4	1.2	1.2	2.1	1.8	1.2	.9	.9	2	.9	.5	1.6	1.0
	2	1.9	2.6	4.1	4.1	3.5	3.0	1.8	1.4	1.3	1.3	1.6	2.3	2.0
	3	3.6	5.1	5.1	5.3	4.4	3.0	2.1	2.1	1.9	2.3	2.6	2.6	3.0
	4	5.8	6.7	6.2	6.5	4.8	3.7	3.0	2.6	2.8	3.3	3.3	3.0	3.6
	5	6.7	7.1	6.9	6.5	5.1	4.2	3.0	3.3	3.7	3.3	3.5	4.2	4.4
	6	8.1	7.6	7.1	6.7	5.6	4.6	3.9	3.9	3.7	3.7	4.2	4.5	5.0
August	1	1.2	.7	1.2	1.2	1.8	1.7	1.6	2.1	1.6	.5	.5	.9	1.1
	2	1.9	2.1	2.5	2.8	3.3	2.8	3.2	3.2	1.6	.7	1.2	1.4	2.0
	3	3.0	3.4	4.4	4.3	3.9	4.1	3.9	3.3	1.6	1.0	2.1	3.0	2.8
	4	4.6	5.3	5.3	4.9	5.1	5.3	4.4	3.3	2.1	2.3	3.7	3.7	3.7
	5	6.5	6.7	6.7	6.9	6.5	5.8	4.9	3.9	3.5	3.9	4.5	3.7	5.0
	6	7.6	7.4	8.1	8.1	6.9	5.8	5.3	4.9	4.9	4.6	4.8	4.1	5.4
September	1	1.4	1.9	1.0	2.6	1.7	1.0	1.1	1.6	1.2	1.1	.5	.5	1.4
	2	2.6	2.9	3.1	2.9	2.4	2.4	2.7	2.4	2.4	1.8	2.0	2.4	2.5
	3	3.4	3.4	4.3	3.8	4.1	3.5	3.5	3.4	2.4	3.1	3.6	4.1	3.7
	4	4.8	5.0	4.8	5.5	5.3	5.2	4.2	3.4	3.6	4.3	5.0	5.0	4.7
	5	4.9	5.2	4.9	5.8	5.4	5.4	4.4	4.0	4.7	5.2	5.0	5.0	5.4
	6	6.3	6.3	6.5	7.0	6.4	6.1	5.2	5.4	6.0	6.3	5.6	5.4	6.2
October	1	.9	.7	.5	.3	.5	.2	.5	.0	.9	.7	.7	1.4	.9
	2	1.4	1.5	1.1	1.0	1.2	.9	.7	1.6	1.8	1.8	2.5	4.0	2.0
	3	3.0	2.3	1.9	1.9	1.9	1.4	2.3	4.0	3.0	3.5	4.3	5.5	3.1
	4	3.8	3.0	2.1	2.3	2.3	2.6	3.5	4.4	4.4	5.3	5.6	5.8	3.9
	5	4.8	3.9	3.5	3.0	3.5	3.8	4.6	6.0	5.8	6.0	6.0	6.0	4.9
	6	5.0	4.3	4.1	4.1	4.8	5.0	6.0	6.7	6.3	6.3	6.3	6.3	5.4
Means	1	1.2	1.0	1.2	1.3	1.6	1.3	1.1	1.4	1.3	.9	.6	1.2	1.1
	2	2.0	2.2	2.5	2.6	2.8	2.4	2.4	2.5	2.3	1.9	2.0	2.1	2.2
	3	3.2	3.3	3.9	3.8	3.9	3.4	3.3	3.5	2.9	2.8	3.1	3.7	3.3
	4	4.4	4.8	4.8	4.8	4.9	4.6	4.3	4.2	4.0	4.1	4.6	4.6	4.3
	5	5.9	5.9	5.8	5.8	5.6	5.4	4.9	4.8	5.0	5.0	4.9	5.1	5.1
	6	6.7	6.6	6.7	6.6	6.4	6.0	5.7	5.8	5.7	5.6	5.4	5.6	5.9

TABLE 2.—Total hourly amounts of precipitation (inches) May-October, for 15 years, 1910-1924, inclusive, Lansing, Mich.

	Hours ending (a. m.) at—											
	1	2	3	4	5	6	7	8	9	10	11	12
May	2.86	2.83	2.18	1.89	1.74	2.99	2.56	2.48	2.40	1.41	1.60	2.25
June	1.04	1.31	1.95	0.94	1.19	1.75	2.40	1.72	2.08	1.17	0.85	3.24
July	1.94	0.87	1.24	1.10	1.41	2.11	1.98	0.52	1.33	1.53	1.61	0.88
August	1.39	1.58	1.00	1.14	0.92	1.29	1.38	1.70	0.97	0.89	1.09	1.87
September	2.41	1.70	2.41	2.32	2.67	3.93	3.01	2.67	1.34	0.97	0.72	1.37
October	2.30	2.70	2.24	1.88	1.49	1.55	2.02	1.44	1.49	2.51	1.73	1.33
Means	1.99	1.83	1.84	1.51	1.57	2.27	2.22	1.76	1.60	1.41	1.27	1.84

TABLE 2.—Total hourly amounts of precipitation (inches) May-October, for 15 years, 1910-1924, inclusive, Lansing, Mich.—Con.

	Hours ending (p. m.) at—											
	1	2	3	4	5	6	7	8	9	10	11	12
May	2.02	1.60	1.94	1.44	1.84	2.86	2.53	2.59	1.96	1.99	2.38	2.11
June	2.16	1.90	2.50	1.86	3.03	2.44	2.56	3.53	2.35	1.68	1.12	1.64
July	1.73	1.23	1.93	4.14	2.77	2.00	1.22	2.08	0.57	1.38	0.94	1.90
August	1.25	1.43	1.70	1.62	1.92	5.39	1.84	4.54	2.64	1.08	0.91	0.64
September	1.23	1.14	1.71	2.66	1.92	1.90	1.91	2.79	2.06	1.17	1.78	1.65
October	1.48	1.19	1.00	1.05	1.04	1.12	0.92	0.87	1.14	1.37	1.30	1.83
Means	1.64	1.42	1.80	2.13	2.09	2.62	1.83	2.73	1.79	1.44	1.40	1.63

TABLE 3.—Percentage of monthly precipitation occurring during six-hour periods, May-October, inclusive, Lansing, Mich.

Month	12 mid-night to 6 a. m.	6 a. m. to noon	Noon to 6 p. m.	6 p. m. to midnight
May	28	24	22	26
June	17	25	30	28
July	23	30	36	21
August	18	20	33	29
September	32	22	22	24
October	32	29	19	20
Means	25	23	27	25

TABLE 4.—Percentage of times 0.01 inch or more of rain has fallen during each hour for the months May-October, years 1910-1924, inclusive, Lansing, Mich.

	Hours ending (a. m.) at—											
	1	2	3	4	5	6	7	8	9	10	11	Noon
May	6.7	7.5	6.7	8.2	8.0	9.7	8.6	8.4	7.3	5.6	6.0	6.4
June	4.7	4.2	6.0	4.4	4.9	6.0	5.3	5.1	6.0	5.6	5.6	4.6
July	4.1	2.8	3.9	4.4	3.0	4.1	3.2	2.4	3.9	2.6	3.4	4.5
August	4.1	4.7	5.2	4.1	4.1	5.0	4.7	3.6	3.6	3.4	3.4	3.6
September	6.9	5.8	7.3	7.5	6.2	8.6	7.3	6.0	5.3	4.9	4.9	4.4
October	9.0	8.8	7.3	6.4	7.3	8.0	5.8	7.3	6.9	7.3	6.7	5.2
Means	5.9	5.6	6.1	5.8	5.6	6.9	5.8	5.5	5.5	4.9	5.0	4.8

	Hours ending (p. m.) at—												Mean
	1	2	3	4	5	6	7	8	9	10	11	Mid-night	
May	6.9	6.0	6.2	6.9	7.5	9.0	8.8	7.5	7.3	7.1	6.2	6.4	7.3
June	3.4	5.8	5.6	5.3	6.2	6.9	6.0	5.8	4.7	5.6	4.2	5.1	5.3
July	5.0	5.4	5.4	5.2	4.7	4.7	3.9	3.2	4.1	3.9	4.1	4.1	4.0
August	3.6	4.5	4.7	3.6	5.4	5.4	6.0	6.4	6.4	4.1	4.4	4.5	4.4
September	4.2	4.2	5.6	5.3	5.6	5.6	6.9	5.1	6.2	5.8	5.1	6.0	5.9
October	6.9	6.7	5.6	6.0	5.6	6.7	6.9	5.8	6.4	8.4	7.5	7.3	6.9
Means	5.0	5.4	5.5	5.4	5.8	6.4	6.3	5.6	5.7	5.8	5.2	5.6	5.6